Requested Patent: EP0357085A1

Title: A COAXIAL-WAVEGUIDE PHASE SHIFTER. ;

Abstracted Patent: EP0357085 ;

Publication Date: 1990-03-07 ;

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Application Number: EP19890116207 19890901 ;

Priority Number(s): IT19880067787 19880902 ;

IPC Classification: H01P1/165; H01P1/18 ;

Equivalents:

AU4003189, AU620637, CA1318370, DE357085T, DE68917548D, DE68917548T, IT1223796, JP2113601, US4982171 ;

ABSTRACT:

The coaxial-waveguide phase shifter consists of a coaxial waveguide section, comprising an external cylindrical conductor (CE) and an internal cylindrical conductor (CI), both hollow; thereinbetween a certain number of irises (I) parallel to one another is inserted. The irises can be differently shaped and can be fixed to the external or to the internal conductor. By replacing the internal cylindrical conductor with a rectangular conductor, the irises can be unnecessary.

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 357 085 A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 89116207.5

(51) Int. Cl.[5]: H01P 1/18 , H01P 1/165

(22) Date of filing: 01.09.89

(30) Priority: 02.09.88 IT 6778788

(43) Date of publication of application:
07.03.90 Bulletin 90/10

(84) Designated Contracting States:
DE FR GB NL

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(54) A coaxial-waveguide phase shifter.

(57) The coaxial-waveguide phase shifter consists of a coaxial waveguide section, comprising an external cylindrical conductor (CE) and an internal cylindrical conductor (CI), both hollow; thereinbetween a certain number of irises (I) parallel to one another is inserted. The irises can be differently shaped and can be fixed to the external or to the internal conductor. By replacing the internal cylindrical conductor with a rectangular conductor, the irises can be unnecessary.

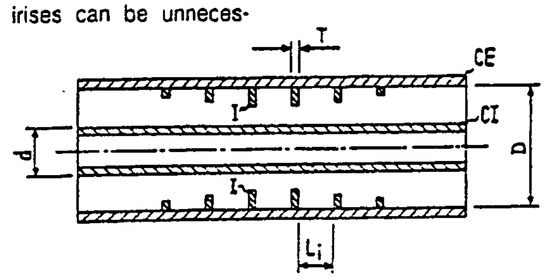

FIG. 1

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A Coaxial-Waveguide Phase Shifter

The present invention refers to devices for telecommunications systems operating at microwaves and more particularly it concerns a coaxial-waveguide phase shifter.

As known, coaxial waveguides consist of a hollow cylindrical conductor, whereinto a second cylindrical conductor is inserted, which is also hollow and coaxial with the external conductor.

Said guides are used whenever mode TE11 propagation of signals belonging to two different frequency bands, even though very distant from each other, are desired. In fact, the internal conductor acts as a conventional circular waveguide, wherein signals belonging to the higher frequency band propagate, whilst the region comprised between the external conductor and the internal one acts as a waveguide wherein signals belonging to the lower frequency band propagate. In addition, the coaxial waveguide presents a pass band, meant as the band comprised between cutoff frequency of mode TE11 and the frequency of the first higher mode, which is wider than the band of the circular waveguide with the same diameter.

Of course, the addition of one or more external cylindrical conductors allows the addition of a corresponding numher of frequency bands propagating in the fundamental mode. A great number of information can thus be transmitted, which can be further doubled by using signals belonging to the same frequency band but with different polarizations.

Analogously to what already devised for circular waveguide systems, which is hence well known, also for coaxial waveguides it is necessary to design and manufacture devices capable of conveniently handling microwave signals propagating inside. More particularly, since signals belonging to the same frequency band, but with different polarizations (namely orthogonal or with opposite rotation directions), are transmitted through the same guide, discriminating devices are required. Among these, phase shifters, and chiefly phase shifters permitting the obtention of a different electrical behaviour in presence of different-polarization signals, are particularly needed. By these devices highly performant microwave components can he obtained, such as double-polarization multiband feeders for ground station or satellite antennas to be used in telecommunications or in radioastronomy domain.

In applications of this kind a phase shifter can he used to convert a circular polarization signal into a linear polarization signal, thus operating as a polarizer with a 90° phase shift, or for rotating the polarization of a linearly polarized signal, keeping the polarization linear: in this case phase shift introduced must be of 180°. A polarizer with a 90° phase shift allows also the separation of circularly polarized signals with opposite rotation directions, supplying two linearly-polarized orthogonal signals, which can easily be separated.

Phase shifters in rectangular or circular waveguide are already known in the literature. A circular waveguide phase shifter has been described in the article entitled "Polarization diversity lowers antenna feed-line noise", by Howard C. Yates et alii, issued in Microwaves, May 1968. It consists of a circular waveguide section, whereinto cascaded irises are placed, composed of two equal circular segments in opposition. A total phase shift of 90 or 180 degrees is obtained by distributing it conveniently on the different irises, generally placed at a quarter-wave spacing at the design-center frequency. Bandwidths of an octave were obtained for 90° ± 1° phase shifts.

The performances required of these components can be thus summarised:

- bandwidth of at least 12% of the center frequency;
- return losses inferior to 30 dB;
- differential phase shift between orthogonal polarizations of ±1°;
- axial ratio inferior to 1.02, in case of circular polarization.

For applications on board a satellite light and reduced-encumbrance devices are also required. Which entails the search for the optimum number of irises the phase shifter is implemented with, since also total length of the device depends on this number.

In the known phase shifters, designed for circular waveguide systems, the desired bandwidths were obtained by using a rather high number of irises; hence the structures obtained are cumbersome.

The inconveniences above are overcome by the coaxial-waveguide phase shifter, provided by the present invention, which presents the above-mentioned performances, which is of small dimensions and can be designed rigorously through the exact synthesis of the equivalent electrical network. The device is also apt to be used on board a satellite, since dielectric parts are not required which present a thermomechanical behaviour not easily predictable owing to expansions, ageing, soldering operations, etc.

The present invention provides a coaxial-waveguide phase shifter, characterized in that it consists of a coaxial waveguide section, comprising external and internal hollow cylindrical conductors,

whereinbetween a certain number of irises parallel to each other is inserted.

The foregoing and other characteristics of the present invention will be made clearer by the following description of a preferred embodiment thereof, given by way of a non-limiting example, and by the annexed drawings wherein:

- Fig. 1 is a logitudinal section of the phase shifter;

- Fig. 2 is a cross section of the phase shifter;

- Fig. 3 shows differently-shaped irises.

As shown in Fig. 1, the phase shifter consists of a coaxial guide section, comprising an external cylindrical conductor CE as well as an internal cylindrical conductor CI, both hollow. The internal diameter of the external conductor and the external diameter of the internal conductor are D and d respectively. There is then a certain number N of irises I , fixed to the external guide. They consist of two opposite plates having the shape of circular segments with rectilinear sides parallel to each other. Plate thickness is T, rectilinear sides are separated by a distance W and spacing between the irises is Li.

The electrical behaviour of the phase shifter depends on the above mechanical parameters, and more particularly on W/D, D/d, T of each iris and on Li and N, which must accurately be defined while designing it. Up to now, the design and optimization of rectangular or circular waveguide phase shifters have been chiefly experimentally carried out, following rather slow and expensive procedures. Besides, while implementing broad-band devices considerably long structures have been obtained, since the electrical models used were not apt to represent structures with irises very close to each other.

A design method which is convenient in avoiding these disadvantages will be now described.

One has first to define total phase shift α_{TOT} introduced by the phase shifter, for instance 90 or 180 degrees, frequency band F1-F2, at which the device is to operate, number N of irises to be inserted into the guide and the distribution of phase shifts α_i allotted to each iris along the guide, e.g. a choice is possible between uniform, binomial, tapered distributions or the like, in function of the performances required as to return losses and bandwidth.

Starting from a matched load and from the last phase shift α_N to be obtained, W/D and L values relating to the last iris can be obtained by using previously prepared design data. To this aim, quadripole equivalent of the cell composed of the guide section and of the iris is derived by expressing the reactances which form it in function of the mechanical characteristics of the iris itself. The relations obtained allow the built up of curves of the phase shift α_i introduced by the cell in function of W/D and T of the iris, where the frequency forms the parameter. Said curves can he then directly used or even better computer-memorised and used in the automated design phase.

The following step is that of implementing the phase shift α_{N-1} by combining in cascade the two cells, to obtain new values W/D and L relating to the last iris but one. Since in this case the load is no longer matched due to the last iris presence, it is necessary to calculate the phase shift of the single cell taking into account multiple reflections. Even in this case it is possible to build up the curves of the phase shift to be obtained in function of the phase shift of the isolated single cell where the reflection coefficient is the parameter.

The process goes on like this up to the obtention of all the iris data.

The device can also use irises with a different shape from that of two opposite circular segments, provided they do not present radial symmetry, since they have to yield a phase shift between incident signals with orthogonal polarizations.

Fig 3 shows different shapes of irises. The iris denoted by a) consists of two sectors of an annulus and that denoted by b) of two rectangular plates. In c) dissymmetry is due to the same internal waveguide presenting a rectangular cross section, while in d) and e) the iris consists of plates having respectively the shapes of circular sector and rectangle, fixed to the internal circular waveguide. Of course, the design requires the equivalent electrical circuit of the iris used.

It is clear that what described has been given only by way of a non-limiting example. Variations and modifications are possible without going out of the scope of the claims.

Claims

1. A coaxial-waveguide phase shifter, which consists of a section of coaxial waveguide comprising an external cylindrical conductor (CE) and an internal conductor (CI), both hollow, characterized in that the internal surface of the external conductor (CE) and the external surface of internal conductor (CI) facing each other have cross sections which present radial asymmetries in orthogonal directions at least at some points along the waveguide axis.

2. A coaxial-waveguide phase shifter as in claim 1, characterized in that said internal conductor (CI) has a circular cross section and said radial asymmetries are irises (I) parallel to each other.

3. A coaxial-waveguide phase shifter as in claim 2, characterized in that said irises (I) are internally fixed to the external conductor (CE) and

consist of two opposite plates having circular arc shape with the rectilinear sides parallel to each other.

4. A coaxial-waveguide phase shifter as in claim 2, characterized in that said irises (I) are internally fixed to the external conductor (CE) and consist of two sectors of an annulus.

5. A coaxial-waveguide phase shifter as in claim 2, characterized in that said irises (I) are internally fixed to the external conductor (CE) and consist of two rectangular plates.

6. A coaxial-waveguide phase shifter as in claim 2, characterized in that said irises (I) are externally fixed to the internal conductor (CI) and consist of two plates shaped as an annular sector.

7. A coaxial-waveguide phase shifter as in claim 2, characterized in that said irises (I) are externally fixed to the internal conductor (CI) and consist of two rectangular plates. 8. A coaxial-waveguide phase shifter as in claim 1, characterized in that said radial asymmetries are obtained by making the internal conductor (CI) with a rectangular cross section.

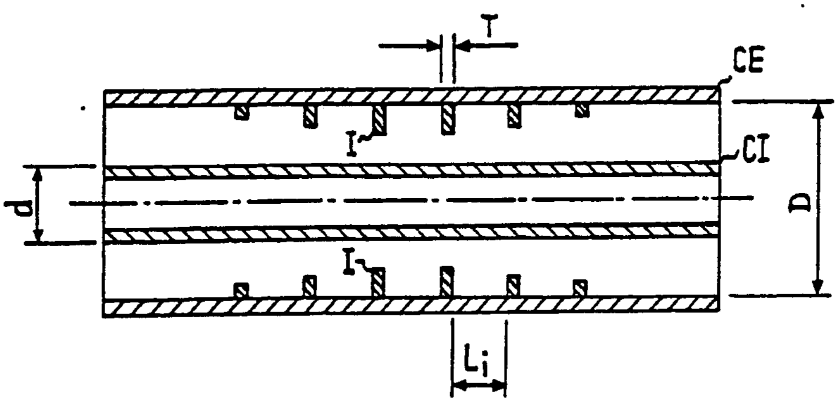

FIG. 1

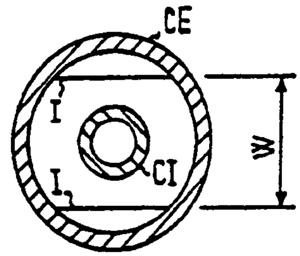

FIG. 2

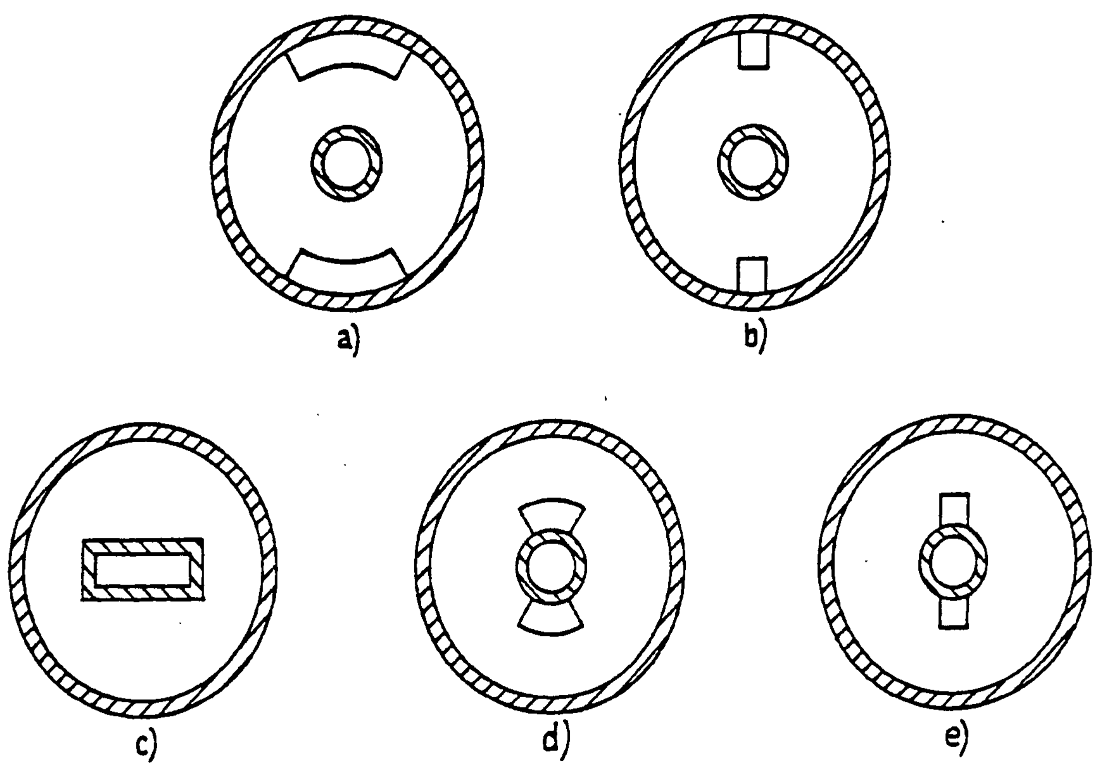

FIG. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 11 6207

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X Y	US-A-4 725 795 (AJIOKA et al.) * Whole document * ---	1,2,4-7 3	H 01 P 1/18 H 01 P 1/165
Y	US-A-3 668 567 (ROSEN) * Column 3, lines 59-62; figure 1 * ---	3	
A	US-A-3 217 273 (ISCH et al.) * Column 2, line 60 - column 4, line 7; figures 2,3 * ---	1,8	
A	DE-C- 934 354 (FUNKSTRAHL GESELLSCHAFT FÜR NACHRICHTENTECHNIK mbH) * Page 3, lines 57-82; figures 4a,b * ---	1,2,4,6	
A	CONFERENCE PROCEEDINGS OF THE 8TH EUROPEAN MICROWAVE CONFERENCE, Paris, 4th-8th September 1978, pages 446-450, Microwave Exhibitions and Publishers Ltd, Sevenoaks, Kent, GB; "Metallic and goubau waveguides with eccentric circular and concentric circular-elliptic cross-sections" * Figure 1b * -----	1,8	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H 01 P

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27-11-1989	DEN OTTER A.M.

CATEGORY OF CITED DOCUMENTS

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